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HIGH MOUNTAIN ENVIRONMENT AND FARMING SYSTEMS
IN THE ANDEAN REGION OF LATIN AMERICA

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HIGH MOUNTAIN ENVIRONMENT AND FARMING SYSTEMS

IN THE ANDEAN REGION OF LATIN AMERICA

INTRODUCTION

Most mountain agricultural systems include valley floors and high plains, as well as steep hillsides. Individual farmers and farm communities may either have access to only one condition, e. g. high plains or steep slopes, or more often to two or more altitudinal levels encompassing different ecological conditions. Therefore, a clear-cut definition of high mountain agriculture is not easy. The government of Perú defines high mountain environments as those located above 2000 masl, independently of topographic and ecological considerations (20). In Ecuador, the definition is related to those particular altitudes (around 2800 masl) where there is a clear differentiation between a "modern" type of agriculture and the traditional agriculture practiced by Andean farm communities (22).

The steep slopes and highlands of tropical America run like a backbone. The Andean range alone, covers nearly 5800 km throughout Latin America. This volcanic mountain chain was chosen by the original settlers and the most flowerishing native cultures evolved along it. During the 16th century, the Spaniards followed this same route and conquered the highland people, imposing a new social order and with it a new way to make use of the land (14).

Latin America and the Caribbean as a whole, have a total of 52 percent of their land area classified as mountains (more than 8% slope). The importance of mountain areas of selected high altitude countries of the region is presented in Tables 1 and 2 developed by Posner and McPherson (15).

TABLE 1. AREA, ARABLE LAND, POPULATION AND AGRICULTURAL OUTPUT IN THE MOUNTAIN REGIONS OF LATIN AMERICA

| COUNTRY | % OF THE TOTAL AREA | ARABLE LAND %* | POPULATION | | % OF TOTAL AGRICULTURAL OUTPUT |
|-----------|------------------------|-------------------|------------------------------------|--|--------------------------------------|
| | | | % OF THE NATIONAL POPULATION | % OF THE POPULATION IN AGRICULTURE | |
| MEXICO | 45 | 20 | 15 | 45 | - |
| GUATEMALA | 75 | 30 | 40 | 65 | 24 |
| COLOMBIA | 40 | 25 | 15 | 50 | 26 |
| ECUADOR | 65 | 25 | 25 | 40 | 33 |
| PERU | 50 | 25 | 25 | 50 | 21 |

* Annual crops only

TABLE 2. PERCENTAGE CONTRIBUTION OF MOUNTAIN AREAS TO THE PRODUCTION OF SELECTED AGRICULTURAL PRODUCTS

| | GUATEMALA | PERU | ECUADOR | COLOMBIA |
|---------------|-----------|------|---------|----------|
| WHEAT | 50 | 60 | 30 | 50 |
| BARLEY | - | 80 | 70 | 70 |
| POTATOES | 75 | 50 | 70 | 70 |
| SHEEP & GOATS | - | 100 | 100 | - |

THE ENVIRONMENT

Natural Vegetation:

The natural vegetation of the Andes is very diversified as an effect of topography, climate, orography and exposure. It has also been greatly modified by man.

Western slope:

In the humid zone of Colombia to northern Perú, a succession of levels of mountain forests starts around 1700-1900 m and goes up with a reduction of the number and diameter of trees towards a herbaceous vegetation "páramos" which are found from 3000 m to the limit of perennial snow at about 4000 m. This natural vegetation has been almost completely destroyed by man, except in the most humid locations.

The western slopes of the Central and Southern Andes (from 4° S) are semi-arid and go progressively to the Chilean desert in Chile. Forests are of a much drier type, composed of xerophytic plants (7).

Eastern slope:

This slope, above 1800 m, is more uniform because of its higher humidity. From Venezuela to Bolivia, there are a succession of forest mountain levels with a complex floristic composition.

Human influence on the Andean vegetation has been prominent and confirmed by signs of occupation for at least 10,000 years. While having greatly contributed to the destruction of the original vegetation, man has also determined the establishment of a new landscape "characteristic" of the Andes, by the introduction at the end of the 19th century of some new plants, such as eucalyptus and kikuyu grass (7).

Soils of the Andean region:

The Andes is a complex mountainous chain which goes from Venezuela to Tierra del Fuego in Chile. Soil formation processes are characterized by intense erosion and sedimentation. In general, soils are not well developed. In the northern humid Andes many inter-Andean valleys enjoy drier climatic conditions. In the western slope, soils are of volcanic origin, while the eastern soils are generally of sedimentary origin. The Andean "altiplano" is a high level mountain basin at over 3500 m. This was produced probably due to block faulting during the uplift of the Andes and is now floored with the sediments of shrunken or extinct lakes. (7).

In the mountain slopes and highlands of the Andean countries, lithosols predominate (41%). The estimated percentage of poor and good soils is 36 and 23, respectively (14).

TABLE 3. DISTRIBUTION OF SOIL QUALITY IN MOUNTAIN SLOPES AND HIGHLANDS OF SELECTED COUNTRIES.

| | | GOOD SOILS DEEP | | POOR SOILS DEEP SHALLOW | | LITHOSOLS |
|-----------|-----------------|--------------------|--|---------------------------------|---------|-----------|
| VENEZUELA | km ² | 101.610 | | 308.520 | 31.050 | 56.610 |
| | % | 21 | | 62 | 6 | 11 |
| COLOMBIA | km ² | 66.240 | | 146.841 | 133.560 | 141.210 |
| | % | 14 | | 30 | 27 | 29 |
| ECUADOR | km ² | 55.790 | | 55.204 | 0 | 65.790 |
| | % | 32 | | 31 | 0 | 37 |
| PERU | km ² | 101.520 | | 78.753 | 0 | 470.250 |
| | % | 16 | | 12 | 0 | 72 |
| BOLIVIA | km ² | 184.860 | | 57.600 | 0 | 196.065 |
| | % | 42 | | 13 | 0 | 45 |
| GUATEMALA | km ² | 31.680 | | 12.420 | 45.513 | 0 |
| | % | 35 | | 14 | 51 | 0 |
| TOTALS | km ² | 541.700 | | 659.338 | 210.123 | 929.925 |
| | % | 23 | | 27 | 9 | 41 |

Generally, soil classifications and soil maps of mountainous regions are inadequate and more attention could usefully be paid to producing maps to assist in land use planning. Many of the international classification systems presently in use are inadequate, and it might be useful to take more into account the often highly developed and practical indigenous classification system (8).

One well documented local soil classification system is that of Quechua-speaking communities located in the highlands of the Department of Cusco (16).

Soils are characterized by means of indicator plants and according to topographic, climatic and various other factors and characteristics. Farmers have thus developed an applied system which is based on experience and observations and suits well their needs. A few examples, with titles in Quechua, which is the native language of the Inca Empire, are provided below for illustration.

Indicator plants:

Determine the soil quality, limitations, and potential.

- * Liapha pasto (a gramineae). When it grows well, soil is very poor and yields will be low.
- Layo (Trifolium peruvianum). This species grows only in compacted and stony soil. This means that soil preparation will be an important limitation.
- Philli pilli (Hypochaeris sp.). Grows well in wet and swampy soils. These soils are not appropriate for farming.
- Salvia (Salvia officinales). Indicates a high quality and fertile soil well protected from frost.

Classification by location:

- Puna allpa: lands located at the Puna altitudes and very prone to night frosts.
- Yunga allpa: warmer lands not prone to frost problems.

Classification by climate:

- Chiri allpa: lands appropriate for dry farming and where the "laymis" system (rotational cropping) is practiced.
- Qoñi allpa: irrigated lands used for annual cropping normally without fallow period.

Classification by topography:

- Waygo allpa: lands found in the deep valleys.
- Pampa allpa: flatlands.
- Qhara allpa: lands found in gentle slopes.
- Mogo allpa: hilly lands.
- Phukru allpa: lands found in abrupt slopes.

The system also provides very precise and detailed classifications by irrigation, humidity, texture and soil compaction (16). The system is widely used for land assignment to community members on the basis of their social status, marital status, and age.

Population pressures have led to a widespread removal of forests for fuel and for agriculture and in many areas increased number of animals have resulted in overgrazing. Both deforestation and overgrazing have increased the problem of soil erosion. This is probably the single most important problem to be confronted when future exploitation of many mountainous regions occur. In the Central Andes, for example, it is estimated that between 50 and 60% of the agricultural area is affected by erosion to a greater or lesser degree. Although gulley erosion is widespread and spectacular, sheet erosion is generally considered to be responsible for even greater soil losses amounting to many million of tons of montane topsoil, annually (8).

Apart from the immediate and long-term effects of erosion on the agriculture of the mountains themselves, downstream effects such as silt deposition, more severe flooding in the wet seasons and lower water levels in the dry seasons, can be even more serious. However, at present, there are few measurements of erosion losses.

The direct effects of different soil types, agricultural practices, animal species, crops cover, etc. on erosion in mountain areas are still poorly understood. While actual estimates of erosion are sometimes within acceptable levels for sustainable agriculture, the downstream effects of soil losses of this magnitude are largely unknown. Clearly, much more research in this area is needed (8).

Climate:

Harshly variable climate leads to erratic food supplies, thus contributing to malnutrition and an ever-present threat of famine in much of the world (1). High mountains are obviously not free from climatic hazards and, in fact, some climatic factors specially frost, hail, floods, drought and winds are often exacerbated in high mountain environments.

Air and soil temperature:

The altitudinal air temperature gradient is of about 0.6° per 100 m. In the northern Andes, with limited seasonal temperature variation, agriculture goes up to about 3500 m. In the other zones, water and temperature limitations shorten the growing period but in turn during the warm season agriculture may climb up to 4200 m (7).

The diurnal range between maximum and minimum temperatures is also important and varies with altitude in a limited range in the equatorial zone. This range is much larger in southern tropical areas and is linked with the occurrence of frost. Variation in average temperatures from one season to another is mainly due to variation in the minimum temperatures, while maximum temperatures tend in general to be more steady throughout the year.

Frost in the Andes has two origins: the "white frost" is caused by a local cooling of the air above the ground to values below 0°C , which causes some

80% of the frost occurrences. Black frost is caused by the effect of the penetration of cold air masses from the south, consisting of air at below freezing temperatures (7)

The transfer of agricultural technologies from low elevation temperature regions to high altitude tropical ones, having the same mean temperatures, is often not possible because of the extreme diurnal changes. In addition daylength requirements of temperate species are often not met in the tropics, even if temperature regimes are acceptable (8).

Ellemberg and Ruthsatz (6) define five thermic regions for the Andean region and list predominant plant species.

TABLE 4. THERMIC REGIONS OF THE ANDEAN ZONE

| REGION'S TEMPERATURE | | MEAN TEMPERATURE °C | AGRICULTURAL ACTIVITY |
|----------------------|-----------------|---------------------|--|
| 1 | Freezing | 2.5 | Reserved pastures |
| 2 | Extremely cold | 5 | Grazing |
| 3 | Very cold | 7.5 | Grazing-cultivated pastures |
| 4 | Cold | 10 | Grazing-crops (potato, barley, quinoa) |
| 5 | Moderately cold | 13 | Crops (maize)-cultivated pastures |

A representation of the main agroecological zones of the Southern Andes in Peru is shown in Fig. 1. The thermic and altitudinal differences contribute to explain the high genetic variability encountered in the area.

Mean monthly temperatures from five sites in the Andes are shown in Fig. 2 (OMM). The minimum temperatures are of course of major significance for the cropping cycle. This is illustrated for three sites of the Peruvian Andes in Fig. 3.

The mean minimum, the extreme minimum, the mean maximum, and the extreme maximum temperatures, as well as the number of days with frost in Patacamaya, Bolivia (3.800 masl) are shown in Table 5. Under these conditions bitter potatoes and barley (when rainfall is appropriate) and quinoa (even in low rainfall years) are the best adapted species and the main components of the daily diet of the population.

TABLE 5. TEMPERATURE AND NUMBER OF DAYS WITH FROST IN PATACAMAYA, BOLIVIA

| AGRICULTURAL SEASON | MMT | EMT | MMaxT | EMaxT | DAYS WITH FROST |
|------------------------|------|------|-------|-------|--------------------|
| 1980-1981 | -0.3 | -5.4 | 17.7 | 20.6 | 151 |
| 1981-1982 | -2.9 | -6.2 | 18.0 | 21.2 | 162 |
| 1982-1983 | -1.0 | -3.5 | 19.6 | 22.6 | 151 |
| 1983-1984 | 0.9 | -7.3 | 18.1 | 21.4 | 161 |

Rainfall and water availability:

Rainfall and water availability is generally adequate in the equatorial zone, included between 8° and the equator. Southwards rainfed agriculture is limited to one season which shortens with the latitude. In general, problems due to water deficiency exist above the level of 2000-2500 m.

Rainfall is certainly the major single factor for agricultural production in the Andes. The region is reasonably well covered with meteorological stations but unfortunately long series allowing adequate probability analyses are very rare.

Other forms of precipitation occur in the region. Snow is of indirect interest because it falls outside the growing season or outside the cropping areas. Nevertheless, it is of interest for its contribution to the groundwater storage. Hail may occur at lowland stations but is common at the altitude of 3000 m and over.

Water balance:

Evapotranspiration data combined with rainfall data is very important for the calculation of the length of the growing season and to determine to what extent crops water requirements are satisfied during this vegetative cycle. An example for Huancayo, Perú, is shown in Fig. 4.

Mean monthly, annual rainfall and potential evapotranspiration figures (7) for selected sites of the Andes in millimeters are shown in Table 6.

TABLE 6. MEAN MONTHLY ANNUAL RAINFALL AND POTENTIAL EVAPOTRANSPIRATION
FIGURES FOR SELECTED SITES OF THE ANDES

| STATIONS | MONTHS | | | | | | | | | | | | YEAR | YEAR |
|------------------|--------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|------|
| | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | TOT | PET |
| <u>VENEZUELA</u> | | | | | | | | | | | | | | |
| Merida | 49 | 35 | 42 | 165 | 256 | 173 | 120 | 122 | 183 | 242 | 190 | 91 | 1668 | 1225 |
| <u>COLOMBIA</u> | | | | | | | | | | | | | | |
| Bogotá | 51 | 50 | 69 | 100 | 105 | 57 | 47 | 41 | 52 | 144 | 138 | 85 | 939 | 1084 |
| Pasto | 53 | 59 | 64 | 93 | 56 | 54 | 28 | 30 | 35 | 106 | 112 | 101 | 790 | 952 |
| <u>ECUADOR</u> | | | | | | | | | | | | | | |
| Ibarra | 46 | 49 | 63 | 110 | 73 | 41 | 8 | 14 | 27 | 72 | 75 | 50 | 628 | 1060 |
| Quito | 123 | 135 | 154 | 179 | 128 | 50 | 19 | 22 | 82 | 133 | 114 | 104 | 1243 | 1008 |
| Ambato | 40 | 43 | 51 | 62 | 50 | 35 | 21 | 21 | 28 | 50 | 49 | 35 | 485 | 1069 |
| Cuenca | 72 | 78 | 85 | 101 | 66 | 52 | 22 | 20 | 51 | 114 | 96 | 66 | 823 | 1050 |
| <u>PERU</u> | | | | | | | | | | | | | | |
| Cajamarca | 96 | 86 | 102 | 86 | 30 | 6 | 5 | 10 | 27 | 91 | 77 | 77 | 693 | 1215 |
| Huancayo | 126 | 107 | 113 | 52 | 28 | 3 | 9 | 19 | 48 | 71 | 66 | 98 | 739 | 986 |
| Cusco | 139 | 130 | 112 | 36 | 9 | 1 | 7 | 7 | 29 | 48 | 68 | 132 | 716 | 1129 |
| Puno | 120 | 135 | 134 | 37 | 14 | 1 | 3 | 4 | 30 | 36 | 53 | 121 | 687 | 1173 |
| Arequipa | 28 | 25 | 8 | 0 | 1 | 0 | 0 | 0 | 2 | 0 | 1 | 3 | 68 | 1184 |
| <u>BOLIVIA</u> | | | | | | | | | | | | | | |
| El Belén | 89 | 79 | 59 | 31 | 30 | 1 | 5 | 12 | 29 | 31 | 52 | 97 | 515 | 912 |
| Patacanaya | 88 | 69 | 47 | 15 | 8 | 2 | 1 | 9 | 37 | 18 | 33 | 76 | 403 | 1049 |
| Oruro | 85 | 79 | 48 | 15 | 6 | 4 | 3 | 9 | 21 | 17 | 32 | 70 | 389 | 1217 |

Source : OMM

Light, duration of the day and photoperiodism:

Duration of the day does not vary very much nevertheless, it can be noted that the difference between the equator and latitude 20°S may be of about two hours (7).

Air humidity:

Although this parameter is generally considered as secondary and has in fact not been dealt with in the previous surveys, some characteristics of air humidity are worth some emphasis, especially in mountainous areas. Air humidity gradient is similar to that of air temperature and is of about 0.52 mb/100 m. The controlling factor of air humidity seems to be the saturation vapor pressure corresponding to the minimum daily temperature. The saturation deficit seems to be relatively constant at all altitudes.

General circulation of the atmosphere:

This circulation is characterized by the presence of high pressure zones in the tropics and the Intertropical Convergence Zone (ITCZ) fluctuation according to the seasons near the equator.

In the lowlands, up to an altitude of 1000 m, the limited movement of the ITCZ generates in most cases a monomodal system of rainfall distribution with a reduction in intensity of the rainfall in the middle of the rainy season.

In the highlands, however, much of the moisture of the large air masses passing across the Andes has been condensed at lower levels and rainfall is mainly due to local convection, with a clear bimodal pattern in sites near the equator (7).

Radiation and sunshine:

In view of the geographical position of the region and of its altitude, the radiation received remains important throughout the year. Altitude also causes large infrared effective radiation losses and low air temperatures.

The radiation balance changes with altitude and latitude. Two sets of stations situated at different altitudes for equatorial and tropical latitudes have been compared. The effective radiation in the area considered may have values as low as 15-20% in equatorial lowlands and as high as 30-40% of the total radiation in the highlands. In addition, there is also a difference in the annual total radiation with altitude, showing an increase in the tropical highlands (7).

Atmospheric pressure:

Atmospheric pressure decreases by about 10.2 millibars for each 100 m increase in altitude. The Altiplano of Central Andes, for example, has an atmospheric reduction of about 30-50% compared to sea level (7). The significance of reduced partial O₂ and CO₂ pressures is not well understood. However, as some plants are known to have increased growth rates with increased partial pressure of CO₂, the opposite may well occur with decreased partial pressure (8).

DEMOGRAPHIC ASPECTS

The total population of the Andes before the arrival of the Spaniards has been estimated from 16 to 18 million by Horkheimer 1973 (9). The number decreased drastically after the conquest and at present the population of the high Andes is estimated at 17 million (12).

A partial breakdown of the actual population, using in some cases selected historic series is presented for some of the Andes countries. A comparison of the population of three selected Departments of Colombia (3) located predominantly in the Andes is presented in Table 8.

TABLE 8. COMPARISON OF THE TOTAL POPULATION OF THREE ANDEAN DEPARTMENTS OF COLOMBIA IN 1938 AND 1986

| DEPARTMENT | POPULATION in 1938 | POPULATION in 1986 | % INCREASE |
|--------------|-----------------------|-----------------------|------------|
| BOYACA | 710.082 | 1.097.600 | 54 |
| CUNDINAMARCA | 819.071 | 1.382.400 | 69 |
| NARIÑO | 465.868 | 1.019.100 | 119 |
| TOTAL | 1.995.021 | 3.499.100 | 75 |

A similar set of data is given below for all Departments of Perú located totally or partially in the high Andes (21).

TABLE 9. COMPARISON OF THE POPULATION IN VARIOUS ANDEAN DEPARTMENTS OF PERU FROM 1940 TO 1972

| DEPARTMENT | % IN HIGH <u>/1</u> ANDES | POPULATION | | | % INCREASE 1940-1972 |
|--------------|------------------------------|------------|-----------|-----------|-------------------------|
| | | 1940 | 1961 | 1972 | |
| APURIMAC | 100 | 258.094 | 288.223 | 307.805 | 19 |
| AREQUIPA | 33 | 86.815 | 128.330 | 175.074 | 101 |
| AYACUCHO | 100 | 358.991 | 410.772 | 459.747 | 28 |
| CAJAMARCA | 100 | 494.412 | 746.938 | 916.331 | 85 |
| CUSCO | 66 | 321.150 | 40.391 | 470.525 | 46 |
| HUANCABELICA | 100 | 244.595 | 302.817 | 331.155 | 35 |
| HUANUCO | 66 | 154.455 | 217.086 | 277.704 | 80 |
| JUNIN | 100 | 428.855 | 521.210 | 691.130 | 61 |
| MOQUEGUA | 50 | 17.076 | 25.807 | 37.280 | 118 |
| PASCO | 100 | - | 138.369 | 176.750 | 27 |
| PUNO | 100 | 548.371 | 686.260 | 779.594 | 42 |
| TOTAL | | 2.912.814 | 3.506.203 | 4.623.095 | 59 |

/1 Estimated by authors

Even though the population of all the Peruvian Departments located in the Andes has increased in absolute terms and in percentage, the biggest increment has been in Lima, the capital city, where for the same period of time the population increased 320%, largely as a result of out migration from the high Andes. The proportion of urban and rural population has also changed, the percentage of rural population was 65, 53, and 41 for 1940, 1961 and 1972, respectively.

The total population of Bolivia (1984) was 6.252.721, and almost 80% lives in the highlands (24). The population breakdown for those Departments located in the Andean range is shown in Table 10.

TABLE 10. POPULATION OF THE ANDEAN DEPARTMENTS OF BOLIVIA

| DEPARTMENT | POPULATION 1982 | % OF TOTAL |
|----------------------|-----------------|------------|
| CHUQUISACA | 435.406 | 7.3 |
| COCHABAMBA | 908.674 | 15.3 |
| LA PAZ | 1.913.184 | 32.3 |
| ORURO | 385.121 | 6.5 |
| POTOSI | 823.485 | 13.9 |
| TARIJA | 246.691 | 4.1 |
| TOTAL IN THE ANDES | 4.712.561 | 79.6 |
| TOTAL OF THE COUNTRY | 5.915.844 | |

A comparison of the population in the Andean Provinces of Ecuador from 1974 to 1982 is presented in Table 11. In this period of time, the rural population has decreased from 58 to 50% (2). The increase in the Andean population was slightly less than for the total (21 to 24%) of the country.

TABLE 11. COMPARISON OF THE POPULATION IN THE ANDEAN PROVINCES OF ECUADOR (1974-1982)

| PROVINCE | POPULATION | | % INCREASE 74-82 |
|-------------------------|------------|-----------|---------------------|
| | 1974 | 1982 | |
| AZUAY | 367.324 | 442.019 | 20 |
| BOLIVAR | 144.593 | 145.949 | 0 |
| CAÑAR | 146.570 | 174.510 | 19 |
| CARCHI | 120.857 | 127.779 | 6 |
| COTOPAXI | 236.313 | 277.678 | 17 |
| CHIMBORAZO | 304.316 | 316.948 | 4 |
| IMBABURA | 216.027 | 247.287 | 14 |
| LOJA | 342.339 | 360.767 | 5 |
| PICHINCHA | 988.306 | 1.382.125 | 40 |
| TUNGURAHUA | 279.920 | 326.777 | 17 |
| TOTAL OF THE ANDES | 3.146.565 | 3.801.839 | 21 |
| TOTAL OF THE COUNTRY | 6.521.710 | 8.060.712 | 24 |

The population figures for the high Andes indicate a steady growth. The implications, limitations, and potential for development and research need to be carefully evaluated. The protection of the environment as well as the need of an increased agricultural output is a difficult challenge for the population and governments of the Andean countries.

SOCIAL ORGANIZATION OF PRODUCTION

It is well documented that around 1500 a.d. in the Inca State or "Tawantinsuyu", two systems of production could be found: the State's and that of the ethnic local groups. The State established and managed productive lands to generate income for itself and for religious purposes. In some cases, the State either supported productive lands or imposed heavy taxes to highly productive local groups.

Despite the above, around the year 1500, the Inca State had decided not to interfere in the capability of the local ethnic groups to feed themselves and support their domestic units of production (13).

Murra (13) concludes that both the State and the ethnic group were significant political and economic forces. The local groups practiced reciprocal obligations by means of which all members participated in land preparation, planting and harvest of crops without remuneration. These obligations included the provision of a new house, built with everyone's effort, for newly weds and free support for old people, orphans, widows or the physically impaired.

One of the most outstanding characteristics of the State and the ethnic groups was the control of a maximum number of vertical ecological levels to permit the access to diverse materials and food stuffs. A well documented example is that of the powerful groups of the Aymara speaking Lupaka, composed of up to 150,000 people. The Lupakas had a main nucleus, close to the Titicaca lake at 3900 masl, and access to the Pacific coast towards the West and "coca" plantation and wood to the East, according to Fig. 6.

The situation, nowadays, for the majority of the Andean communities is one in which access to different ecological levels is still the norm but in a much more limited range, e.g. normally a maximum of 1000 m for a particular community, and often less. Comparatively speaking, communities are characterized by a more obvious isolation and self reliance today, even though trading links may exist between them or with other mountain and

low land communities.

During the Tawantinsuyu, strong social cohesion and organization was a prerequisite for the development of much of the infrastructure on which mountain agriculture has traditionally been dependent on. In recent years, a variety of factors such as improved communications, alternative work in the cities and plantations, and an increasing social mobility have resulted in weakening and disrupting of many of the traditional social structures. In some areas of the Andes, for example, terraces and irrigation systems which may have been maintained for hundreds of years, are falling into disrepair (8).

ANDEAN FARMING SYSTEMS

It is difficult to imagine the development and successful evolution of permanent settlements in the harsh conditions of the Andes close to 3000 masl. A number of factors and specific characteristics have allowed the proliferation of these communities, among them the following are possibly the most relevant (19).

- The Andean region is an important center of domestication of crop and animal species.
- The ingenious modifications and conservation of the terrain to allow the construction of terraces, irrigation systems, and land preparation based on concepts to regulate temperature and water, e.g. "wuarus" and "qochas".
- The prediction of climate for the upcoming cropping season based on natural indicators e.g. behaviour of animals, flowering of certain species, observations of clouds, stars, etc.
- Post-production systems of crop and animal products. The prevalence of only one cropping season in the year and the variability of climatic conditions made necessary the development of food conservation systems. Examples include drying and salting of meat ("charqui"); freezing, squeezing and drying of tubers and potatoes ("chuño"); freezing, washing

squeezing and drying of tubers and potatoes ("tunta or moraya").

- Storage, transportation and accounting systems. Various chronicles give testimony of the enormous food supplies available at the arrival of the Spaniards. It was estimated in 2000 the number of "qolqas" (large silos made of rocks) built in the Central highlands of Peru. The Inca mainways, plus secondary and foot pathways, constitute an intricate and efficient system to transport by "llamas" or foot, products and information to all the Tawantinsuyu. To implement this superb organization, an efficient accounting system based on knots ("kipu") was also developed.

Community farm families have access to individual micro-plots (up to 35 in many cases) at different altitudes spanning from 200 to 1000 m and to communal cropping and grazing lands also at various elevations. The communal lands are administered by the local councils and serve the purpose of providing extra resources to community members and to generate resources for general infrastructure and cultural, ceremonial, and recreational activities.

The above mentioned characteristics plus the climate limitations imposed mostly by altitude and water availability have defined various altitudinal Homogeneous Zone of Production (HZP) where specific crops, pasture lands, and crop rotations predominate. The main Andean sub-regions and important HZP in each sub-region are illustrated in Fig. 7.

For the same agroecological areas depicted in Fig. 1 a qualitative indication of the importance of various crops, pastures, and animals, is presented in Tables 12 and 13.

TABLE 12. PRESENCE AND RELATIVE IMPORTANCE OF CROPS IN VARIOUS AGROECOLOGICAL ZONES

| CROP | AGROECOLOGICAL AREA | | | | | |
|------------|---------------------------|---------|-------|------|-------------|------------------|
| | WEST VALLEY YUNGA ALTA | QUECHUA | PUNA | SUNI | LAKE SHORES | EASTERN SLOPE |
| Potato | x | xx | xx(a) | x | xx | xx |
| Maize | xx | xxx | - | - | - | x |
| Faba beans | xx | xx | - | x | xx | x |
| Barley | x | xx | xx | xx | x | x |
| Quinoa | x | x | - | xx | xxx | x |
| Kañiwa | - | - | x | xx | - | - |
| Peas | x | xx | - | x | x | x |
| Tubers | x | x | x | xx | x | xx |
| Tarwi | - | xx | - | - | x | - |
| Fruits | xx | x | - | - | - | x |

(a) Bitter potato species (S. juzepzukii, S. curtilobum)

x = Unimportant, less than 5% of total area

xx = Important, 5-10% of total area

xxx = Very important, 10-40% of total area

Source : Tapia, M. INIPA, Perú

TABLE 13. PRESENCE AND RELATIVE IMPORTANCE OF ANIMALS AND PASTURES IN VARIOUS AGROECOLOGICAL AREAS

| | AGROECOLOGICAL AREA | | | | | |
|--------------------------|---------------------|---------|------|------|-------------|----------------|
| | WEST VALLEY | QUECHUA | PUNA | SUNI | LAKE SHORES | EASTERN SLOPES |
| <u>Forage</u> | | | | | | |
| Annual crop | x | xx | x | xx | xx | x |
| Perennial Crop | xx | xx | x | xx | xx | x |
| <u>Pasture lands</u> | | | | | | |
| Agricultural by-products | x | xxx | - | x | xx | x |
| Aquatic species | - | - | - | x | xx | - |
| <u>Animal Species</u> | | | | | | |
| Ovines | x | x | x | xxx | x | x |
| Goats | xx | - | - | - | - | x |
| Bovines | xx | xx | x | xx | xxx | x |
| Alpaca | - | - | xxx | x | - | - |
| Llama | x | xx | x | xx | x | xx |
| Guinea pigs | xx | xx | - | x | x | x |

x = unimportant

xx = important

xxx = very important

Source : Tapia, M. INIPA, Perú

In selected communities of the Department of Cusco, Peru (5) three main HZP have been documented.

The maize HZP :

These areas are located between 3400 and 3600 masl., mean temperatures fluctuate between 10 and 12°C, common slopes are from 10 to 20% in some cases arranged in terraces, irrigation is available. Maize predominates in approximately 90% of all plots, Table 14.

TABLE 14. MAIN CROP ROTATIONS IN THE MAIZE HZP.

| YEARS | | | | | |
|---------------------|-------|--------|--------|------------|-------------|
| 1 | 2 | 3 | 4 | IRRIGATION | FREQUENCY % |
| MAIZE | MAIZE | MAIZE | POTATO | YES | 40 |
| MAIZE | MAIZE | POTATO | - - | YES | 25 |
| POTATO OR BARLEY | FABA | MAIZE | MAIZE | YES | 20 |
| MAIZE | WHEAT | FABA | MAIZE | NO | 15 |

Eighty-three of all maize plots are surrounded by one or a few rows of quinoa (Chenopodium quinoa) or tarwi (Lupinus mutabilis) that provides both an extra source of food and protection against some domestic animals. The above rotations could be improved by a more frequent presence of legumes.

The potato, cereals and legumes HZP :

It is found between 3600 and 3800 masl, mean temperature ranges from 8 to 10°C and slopes vary between 15 and 20%. Irrigation is available specially for those rotations that include potatoes. Quinoa is also used to surround plots and on occasions it is transplanted in the irrigated areas, Tarwi (Lupinus mutabilis) is also used in a similar fashion as quinoa. The main crop rotations are shown in Table 15.

TABLE NO. 15. MAIN CROP ROTATIONS IN THE POTATO HZP

| YEARS | | | | | |
|---------------------|--------|------|--------|--------------------|----------------|
| 1 | 2 | 3 | 4 | IRRIGATION | FREQUENCY % |
| POTATO | WHEAT | FABA | BARLEY | YES (Partially) | 25 |
| POTATO | WHEAT | PEAS | BARLEY | NO | 45 |
| POTATO OR QUINOA | BARLEY | PEAS | FALLOW | YES (Partially) | 10 |
| TARWI | BARLEY | FABA | FALLOW | NO | 20 |

The potato, "MUYUYS" and range HZP :

These are lands above 3800 masl, mean temperatures are always below 8°C. These areas are extensive and plots are allocated by the community council

("Muyuys"). Bitter potatoes (Solanum juzepczukii) predominate as well as other Andean Tubers such as oca (Oxalis tuberosa) lizas (Ullucus tuberosus) and añu (Tropaeolum tuberosum). Long fallow periods are very common. The majority of the land, not used for crops, is characterized by the presence of natural pastures. The main rotations are listed in Table No.16.

TABLE NO. 16. MAIN ROTATIONS IN THE BITTER POTATO HZP.

| YEARS | | | | FALLOW YEARS | FREQUENCY % |
|--------------------|-----------|-----------|--------|-----------------|----------------|
| 1 | 2 | 3 | 4 | | |
| BITTER POTATOES | OCA/LIZAS | LIZAS/AÑU | BARLEY | 4 | 10 |
| BITTER POTATOES | OCA/LIZAS | LIZAS/AÑU | BARLEY | 5 | 30 |
| BITTER POTATOES | OCA/LIZAS | LIZAS/AÑU | BARLEY | 6 | 40 |
| BITTER POTATOES | FALLOW | FALLOW | BARLEY | 6-7 | 20 |

The characteristics of two communities, Luquina Grande and Camacani, located in the Titicaca Lake plateau in Puno are described below (11). The altitudinal span of both communities is only of 300 m. in Luquina and 250 m in Camacani, however, three distinct ecological conditions exist, as shown in Fig. 8. The most important crops are barley, potatoes, faba beans and quinoa as indicated in Table 17. Irrigation is not readily available.

Flatlands

This is the more humid and cold area (in terms of number of days with frost), slope is not more than 5%.

Foot Hills :

Land areas are better protected from frost, slope can reach up to 60%. This is the preferred land type for cropping.

Upper Hills:

This is also a frost-prone area characterized by poor and stony soils. Besides natural pastures, bitter potatoes (Solanum juzepzukii, S. curtilobum) and kañiwa (Chenopodium pallidicaulle) withstand these conditions. Barley is also quite common in the Luquina community due to the thermo-regulatory effects of the Titicaca Lake.

TABLE 17. DISTRIBUTION OF THE NUMBER OF INDIVIDUAL PLOTS PER CROP AND IN THE THREE ALTITUDINAL LEVELS.

| | CAMACANI | | | LUQUINA GRANDE | | |
|--------|-----------|-------|-------------|----------------|-------|-------------|
| CROP | FLATLANDS | HILLS | UPPER HILLS | FLATLANDS | HILLS | UPPER HILLS |
| BARLEY | 360 | 468 | 107 | 63 | 245 | 379 |
| POTATO | 273 | 486 | 68 | 50 | 189 | 145 |
| QUINOA | 152 | 91 | 17 | 33 | 47 | 10 |
| FABA | 75 | 147 | - | 19 | 132 | 68 |
| OTHERS | 54 | 208 | 11 | 10 | 87 | 121 |
| TOTAL | 914 | 1400 | 203 | 175 | 700 | 723 |
| % | 36.3 | 55.6 | 8.1 | 11.0 | 44.0 | 45.0 |

The main and secondary crops are arranged in various rotations and inter-cropping systems depending on soil characteristics and availability of organic and inorganic fertilizers. These aspects determine also the length of the fallow periods. A few examples are shown in Table No. 18.

TABLE No. 18. CROP ROTATIONS IN TWO COMMUNITIES OF PUNO.

| YEARS | | | | | | COMMUNITY |
|-------|-------|---|-----------|-----------|--------|-----------|
| 1 | 2 | 3 | 4 | 5 | FALLOW | |
| P | B | Q | NEW CYCLE | | NO | LUQUINA |
| P | Q | B | F | NEW CYCLE | | CAMACANI |
| B | P | F | P | Q | NO | LUQUINA |
| P | OCA | B | FALLOW | | 3 | CAMACANI |
| P | Q | B | FALLOW | | 2-3 | LUQUINA |
| P | ISAÑO | Q | B | F | 2-5 | CAMACANI |

P= potato B= barley Q= quinoa F= faba beans

Another well documented site in terms of cropping system in different HZP is that of Coporaque in the Department of Arequipa (25). Coporaque falls within the Colca River Basin System, which is considered as a dry inter-andean valley on the west side of the Southern Andes.

Rainfall is a major limitation only 349 mm/year, mean annual temperature is 10.4°C (12.3°C in December, 3.2°C in April).

Animal and crops production are mainly for subsistence with limited marketing and/or product exchange. The range of hectares owned by a single farmer is 0.25 to 7.0 usually with plots at different altitudes. All the family members participate in farm work.

The three distinct HZP are described below:

- River floor: 3350 to 3450 masl. Soils are alluvial, highly fertile (mostly sandy loams). Maize is the predominant crop. Barley and faba beans are found to a lesser extent.
- Plains: 3450 to 3600 masl. Soils are deep and good (mostly clay loams with little or moderate slope). Terraces are common. The main crop is barley. Other important crops include faba beans and quinoa. Important rotations are: barley-faba beans-quinoa-potatoes, and potatoes-barley-faba beans-quinoa-potatoes.
- Slopes: 3600 to 3750 masl. Terraces prevail. The most important activity is animal production. Alfalfa predominates as a cultivated species, a few barley and faba beans plots can be found. Identified rotations included faba beans-barley, and potatoes-faba beans.

In general, the terrace areas are irrigated. This technology has existed for centuries as an answer to limited rainfall.

The widespread use of barley is possibly due to the guaranteed market prices offered by the malt factories. Alfalfa is important for those farmers that migrate temporarily because it thrives well under low management.

In the Department of Ayacucho, topography conditions makes the altitudinal span for agricultural activities even more dramatic. Members of the San Jose and Qasangay communities have access to lands between 3100 and 4100 masl. (IICA/IDRC). Three altitudinal HZP are well differentiated as shown in Fig. 9.

The maize HZP :

It is found between 3100 and 3400 masl. Maize intercropped with quinoa, sweet peas or squash are the predominant patterns.

The potato and cereal level:

It extends from 3400 to 3800 masl. Important crops include potato and barley as monocrops and crop associations such as faba beans and quinoa.

The natural pastures HZP :

Natural pastures predominate from 3800 to 4100 masl and animals graze in these areas specially during the rainy season.

In contrast to Ayacucho, farm communities located in the Central highlands of Bolivia have a more limited altitudinal span and therefore the HZP are not well differentiated as in the case of Peru (23). In these two areas altitudes vary between 3800-4000 and 3600-3800 masl, respectively.

A recent characterization of the Pomani community done by the Instituto Boliviano de Tecnología Agropecuaria (IBTA), Bolivia (10), shows that the four key production elements are barley, potato, quinoa and domestic animals, as indicated in Table No. 19.

TABLE NO. 19. AVERAGE NUMBER OF HA AND ANIMALS PER FAMILY IN THE POMANI COMMUNITY, BOLIVIA

| COMMODITY | HECTARES | NUMBER |
|-----------|----------|--------|
| BARLEY | 1.57 | |
| POTATO | 0.62 | |
| QUINOA | 0.58 | |
| WHEAT | 0.30 | |
| OTHERS | 0.16 | |
| TOTAL | 3.23 | |
| BOVINES | | 3.5 |
| OVINES | | 29.4 |
| POULTRY | | 4.2 |

The average family size is 6 members (2 males and 2 females older than 12 and 2 children younger than 12). Any person above 12 years assumes full responsibility in agricultural production. Youngsters and children before reaching 12 years participate monthly in cattle upkeep. Sharing of labor is very common by means of "Ayni" (exchange of labor on an individual basis) or "Minka" (exchange of labor on a group basis).

Available land to an individual family can be differentiated in three ways: "Sayañas" or land where the family lives and has a few crops and pastures (about 30%); "Aynoca", lands distributed annually or cultivated communally but utilized individually; community lands are mostly used for grazing.

A CASE STUDY OF A PEASANT COMMUNITY IN THE SOUTHERN ANDES : AMARU, CUSCO, PERU

The HZP of the Amaru community have been previously described. Other aspects of this community are discussed to illustrate biological and socio-economic characteristics and interactions (5, 19).

The spatial distribution of family plots in the three HZP (Table 20) emphasizes the notion of the diversity of altitudinal levels and cropping patterns. Out of the total number of plots (1610), seventy-five percent corresponds to monocrops and twenty-five percent to intercrops.

TABLE 20. SPATIAL DISTRIBUTION OF FAMILY PLOTS IN THE AMARU COMMUNITY, CUSCO, PERU

| | HZP - LOW AND MIDDLE | | | HZP - HIGH | |
|------------------------|----------------------|--------|------------|------------|------------|
| | NO. PLOTS | | AREA IN HA | NO. PLOTS | |
| | IRRIGATED | UPLAND | | | AREA IN HA |
| Maize | 23 | - | 2.75 | - | - |
| Intercropped maize | 177 | - | 21.19 | - | - |
| Potato | - | 58 | 15.31 | 163 | 37.42 |
| Potato/barley | 63 | - | 15.21 | - | - |
| Potato + tubers | - | 1 | 0.34 | - | - |
| Barley | - | 313 | 35.06 | - | - |
| Faba bean | 27 | 159 | 17.62 | - | - |
| Intercropped faba bean | 2 | 8 | 1.07 | - | - |
| Wheat | 33 | 159 | 17.14 | - | - |
| Tarwi | - | 54 | 4.88 | - | - |
| Intercropped tarwi | 1 | - | 0.03 | - | - |
| Peas | 24 | 53 | 6.52 | - | - |
| Intercropped peas | 2 | 5 | 1.07 | - | - |
| Quinoa | 14 | - | 1.36 | - | - |
| Intercropped quinoa | 1 | - | 0.15 | - | - |
| Oca | - | 4 | 0.14 | 56 | 8.28 |
| Intercropped oca | - | 1 | 0.02 | - | - |
| Lizas | - | 4 | 0.22 | 66 | 8.97 |
| Intercropped lizas | - | - | 0.07 | 32 | 4.83 |
| Intercropped añu | - | - | - | 66 | 6.38 |
| Vegetables | 15 | - | 1.43 | 3 | 0.17 |
| Pastures | 21 | 1 | 1.50 | - | - |
| TOTAL | 403 | 821 | 142.91 | 386 | 66.05 |

Family ownership of plots and the number of families per category are presented in Table 21. In most cases, families have between 21 and 30 plots in the various HZP. On the average each family has a cultivated area of 1.1 ha, from 1.5 to 2.0 ha as fallow, about 0.2 ha of individual grazing apart from the community grazing fields. A representation is provided in Fig. 10.

TABLE 21. RANGE OF NUMBER OF PLOTS OWNED BY FAMILIES IN THE COMMUNITY OF AMARU, CUSCO, PERU

| NUMBER OF PLOTS | NUMBER OF FAMILIES | % |
|-----------------|--------------------|-----|
| 0 - 10 | 21 | 11 |
| 11 - 20 | 58 | 30 |
| 21 - 30 | 85 | 44 |
| More than 31 | 29 | 15 |
| TOTAL | 193 | 100 |

Table 22 describes the main crops areas, yields and amount of each crop availability for family consumption. Clearly tubers, as well as barley and faba beans are the main components of the diet.

TABLE 22. CROP AREA, YIELDS, AND AVAILABILITY FOR FAMILY CONSUMPTION

| CROP | AREA m ² | YIELDS RANGE KG/HA | AVERAGE KG/HA | AVAILABILITY KG/FAMILY/YEAR |
|------------|---------------------|-----------------------|------------------|--------------------------------|
| Potato | 3580 | 5000 - 15000 | 6500 | 2300 |
| Maize | 1140 | 400 - 1400 | 950 | 108 |
| Barley | 2160 | 600 - 1500 | 1336 | 290 |
| Faba Beans | 960 | 700 - 1600 | 1450 | 160 |
| Wheat | 880 | 500 - 1200 | 1050 | 93 |
| Tarwi | 270 | 400 - 800 | 640 | 17 |
| Peas | 380 | 280 - 600 | 780 | 29 |
| Quinoa | 185 | 500 - 1200 | 930 | 17 |
| Oca | 440 | 12000 - 16000 | 14800 | 650 |
| Lizas | 660 | 11000 - 15000 | 13500 | 890 |
| Añu | 415 | 11000 - 16000 | 14200 | 580 |
| Area | 11010 | | | |

Animal inventory for the whole community and animal production per family are indicated in Tables 23 and 24. In absolute numbers, ovines and guinea pigs are by far the most important commodities. Out of the 130 kg of meat

TABLE 23. ANIMAL INVENTORY FOR THE AMARU COMMUNITY, CUSCO, PERU

| SPECIES | AVERAGE/FAMILY | RANGE | TOTAL |
|-------------|----------------|--------|-------|
| Bovines | 3 | 0 - 6 | 579 |
| Ovines | 13 | 0 - 40 | 2509 |
| Camelids | 3 | 0 - 12 | 578 |
| Horses | 1 | 0 - 2 | 193 |
| Swine | 3 | 0 - 4 | 580 |
| Guinea Pigs | 11 | 7 - 13 | 2123 |
| Poultry | 4 | 0 - 6 | 772 |

TABLE 24. ANNUAL ANIMAL PRODUCTION PER FAMILY (AVERAGE OF THREE YEARS)

| SPECIES | SLAUGHTERING | LIVE WEIGHT/KG | MEAT IN KG |
|-------------|--------------|----------------|------------|
| Bovines | 0.6 | 200 | 60 |
| Ovines | 1.3 | 25 | 17 |
| Llama | 0.5 | 100 | 25 |
| Swine | 2.0 | 20 | 24 |
| Guinea Pigs | 10.0 | 0.7 | 4 |
| Poultry | 2.0 | 2.0 | <u>2</u> |
| | | | 130 |

available per year per family approximately 60% is sold and 40% is consumed, specially in ceremonial occasions and holidays.

The use and distribution of hand labor of the community as a whole and the average of individual families is found in Tables 25 and 26.

TABLE 25. HAND LABOR USE IN THE COMMUNITY OF AMARU, CUSCO, PERU

| CROP | HA | HAND LABOR PER HA | TOTAL HAND LABOR USE (193 families) | HAND LABOR/ FAMILY |
|------------|------|----------------------|---|-----------------------|
| Maize | 22.0 | 95 | 2093 | 10.0 |
| Potato | 67.9 | 160 | 10870 | 56.3 |
| Barley | 41.7 | 50 | 2088 | 10.8 |
| Faba Beans | 18.6 | 87 | 1622 | 8.4 |
| Wheat | 17.1 | 50 | 857 | 4.4 |
| Tarwi | 5.2 | 56 | 292 | 1.5 |
| Peas | 7.4 | 61 | 453 | 2.3 |
| Quinoa | 3.6 | 130 | 465 | 2.4 |
| Oca | 8.6 | 95 | 813 | 4.2 |
| Lizas | 12.7 | 95 | 1209 | 6.3 |
| Añu | 7.9 | 95 | 156 | <u>0.8</u> |
| | | | | 108.2 |

TABLE 26. ANNUAL HAND LABOR DISTRIBUTION OF AN AVERAGE FAMILY OF FIVE PEOPLE (EQUIVALENT TO 3.5 ADULTS)

| AVAILABLE MAN-DAYS 3.5 x 365 - 324 (holidays) | MAN-DAYS/YEAR |
|---|---------------|
| Agricultural activities | 108 |
| Animal production activities | 200 |
| Community activities | 50 |
| Commercialization | 40 |
| Out-migration | 130 |
| School (Children) | 202 |
| Handcrafts | 40 |
| Domestic activities | 160 |

In Fig. 11 an integration of the different biological and socioeconomic components and relationships of a family in the Amaru community, is presented. The complexity and interactions depicted in the figure are obvious. As a summary, the authors have estimated that the family income in Amaru is \$994 US per year, and if the foodstuffs consumed by the family are added, the gross family income is \$1646 per year. Comparatively the gross income in the community of Apopata (specialized in animal production - average 80 ovines) is only \$910.

The above data and the experience of several research groups in the Andes suggest that a family with access to more HZP not only gets a more balanced diet but also increases its income substantially while reducing risk. Families having access only to the higher HZP get a significant reduction in income (sometimes as low as 6% of the total of other families), given the fact that grazing, plus growing of bitter potatoes and barley, are the only possible enterprises.

CONCLUSIONS

The high Andes mountains of Latin America present an impressive diversity in terms of environment, climate and people. This region is the center of domestication of important crops and animals that allowed the development of the Inca Empire. After a sharp decline in the total population, upon arrival of the Spaniards, the region's population is back to the original figures of 1500 and growing steadily. This fact jointly with a deterioration of the environment due to destruction of the forest, overgrazing and erosion, poses an immediate challenge to the Andean governments and people. Research and development efforts must address this new reality and propose along with the prevailing farm communities, sustainable farming systems adapted to the local conditions.

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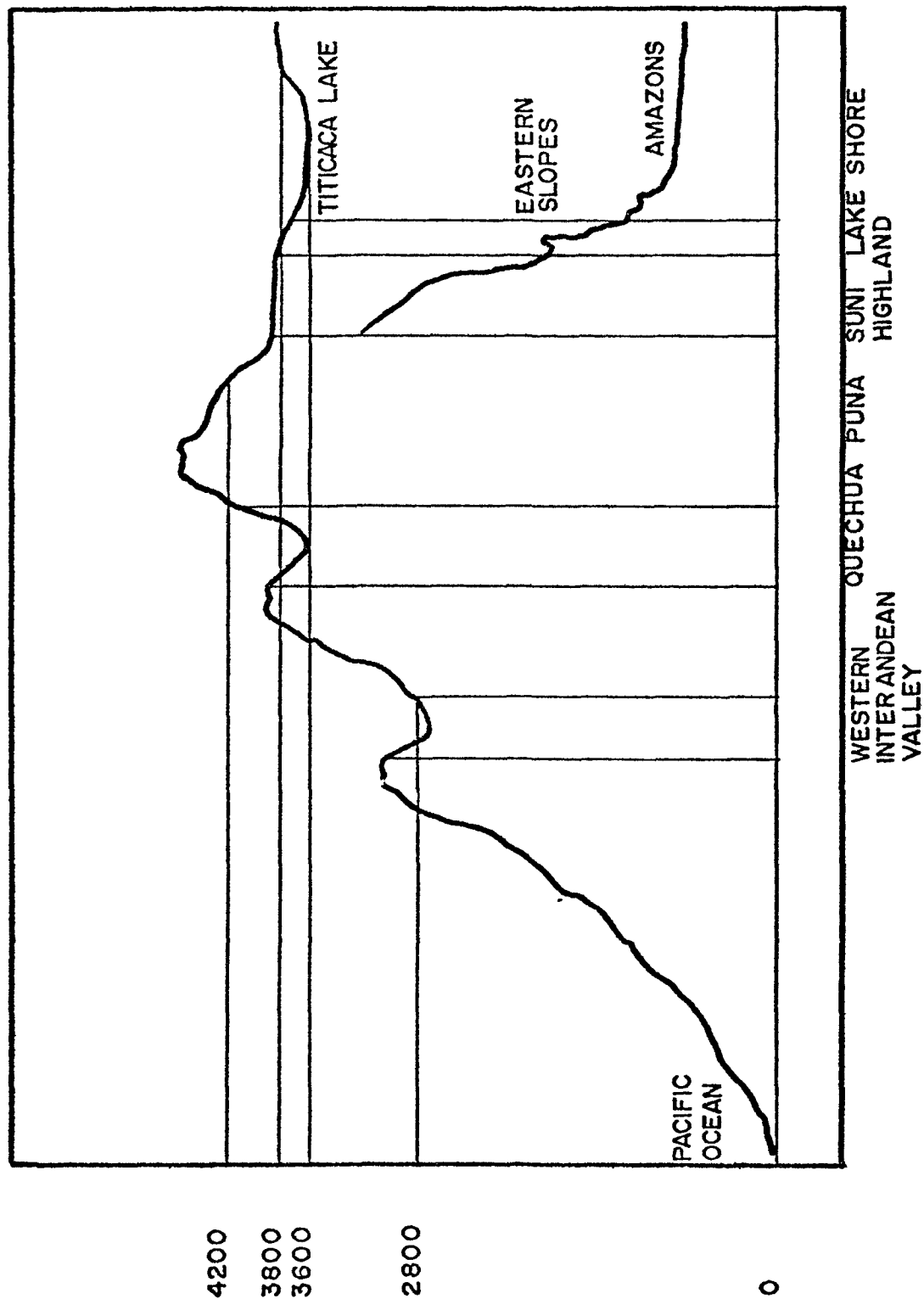
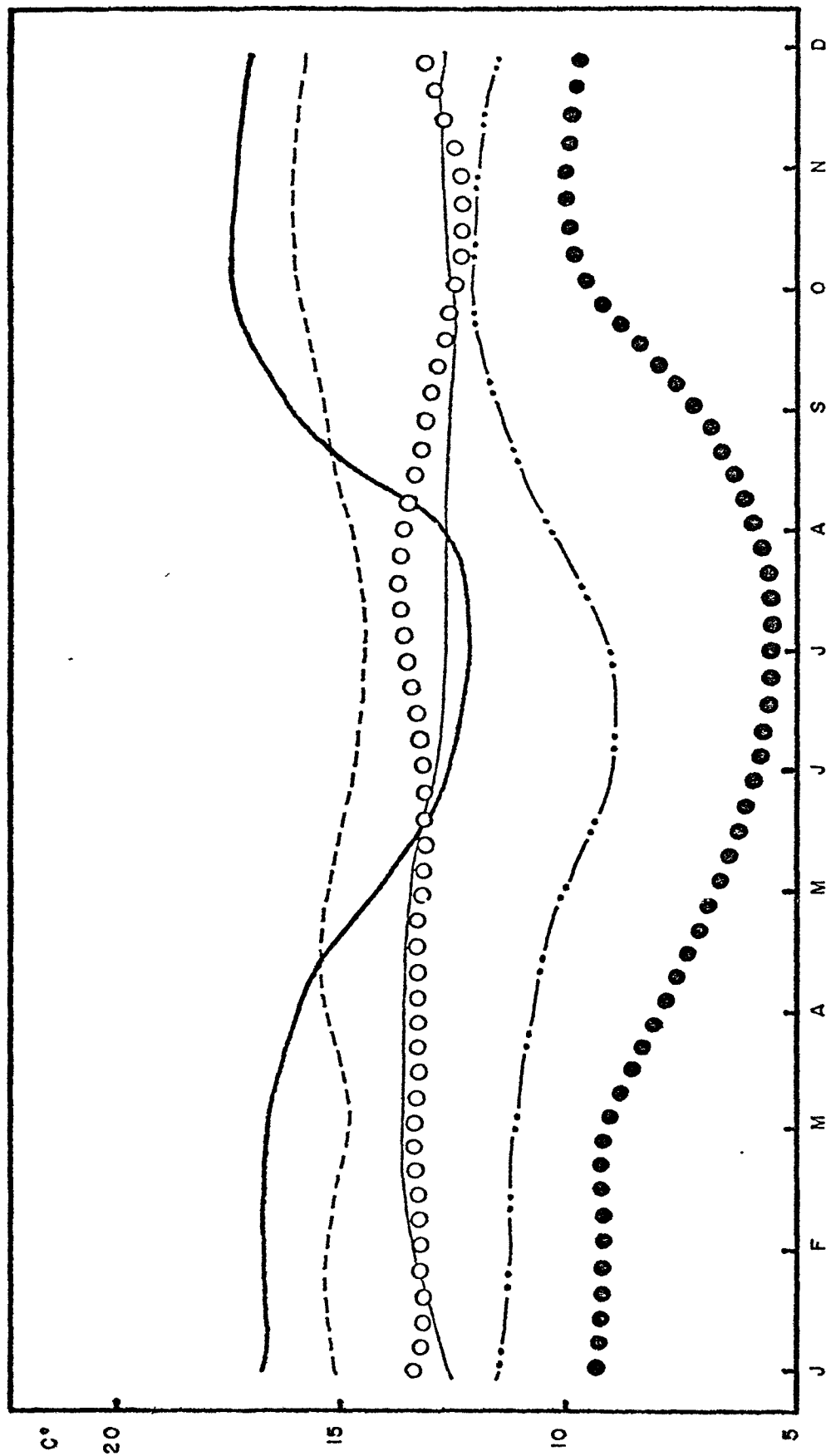


FIG.1 AGROECOLOGICAL ZONES IN THE SOUTHERN ANDES OF PERU.



0437 N - BOGOTA ——— 2560 m.
 0015 S - QUITO ○ ○ ○ 2818 m.
 0613 S - CHACHAPOYAS - - - 2425 m.
 1202 S - HUANCAYO — · · — 3300 m.
 1550 S - PUNO (GR. SALC.) ——— 3852 m.
 1902 S - SUCRE ● ● ● 2750 m.

FIG.2 MEAN MONTHLY TEMPERATURES
IN FIVE ANDEAN SITES.

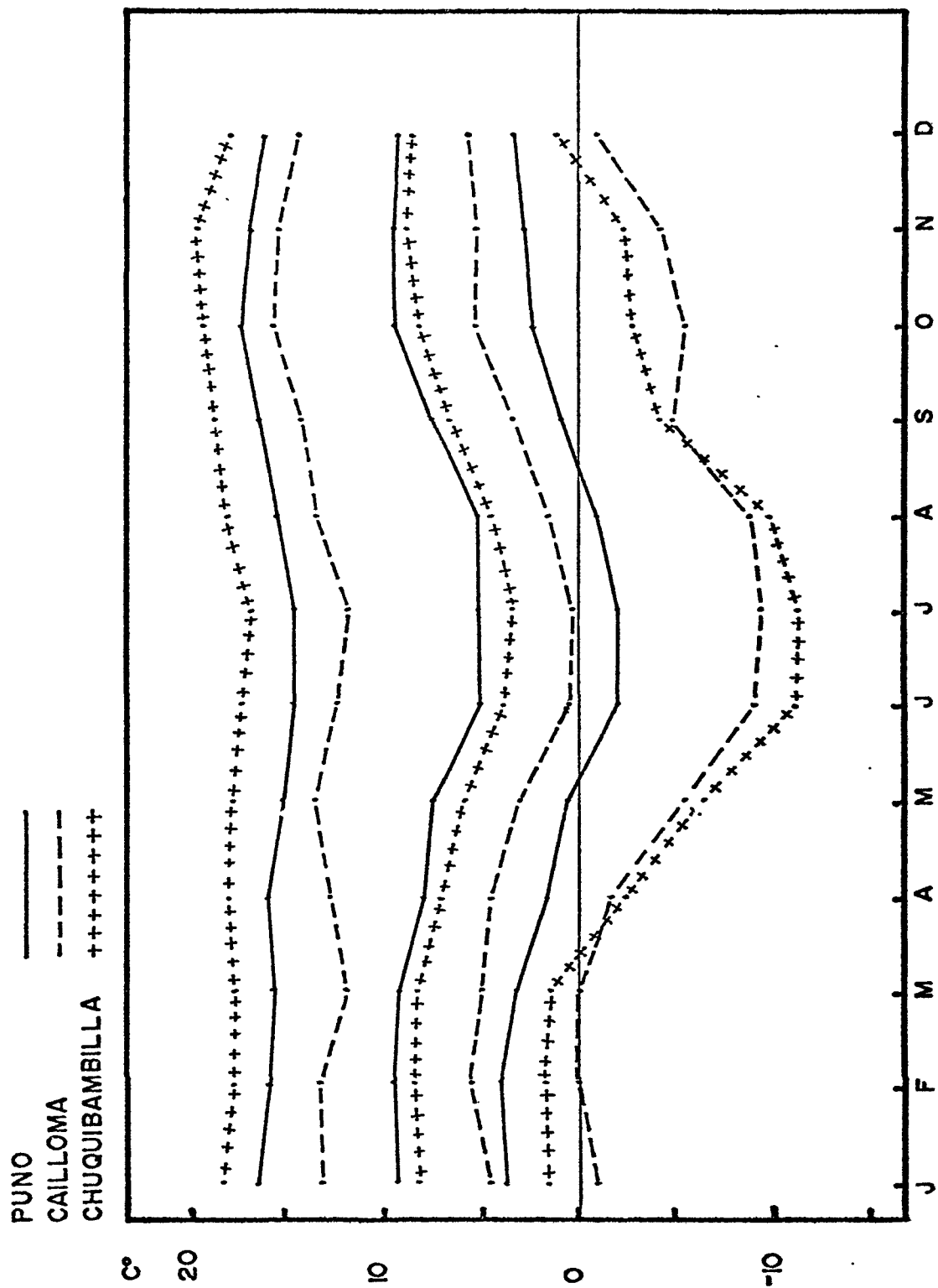


FIG.3 VARIATION OF MAXIMUM, MINIMUM AND MEAN TEMPERATURES IN THREE SITES OF THE PERUVIAN ANDES

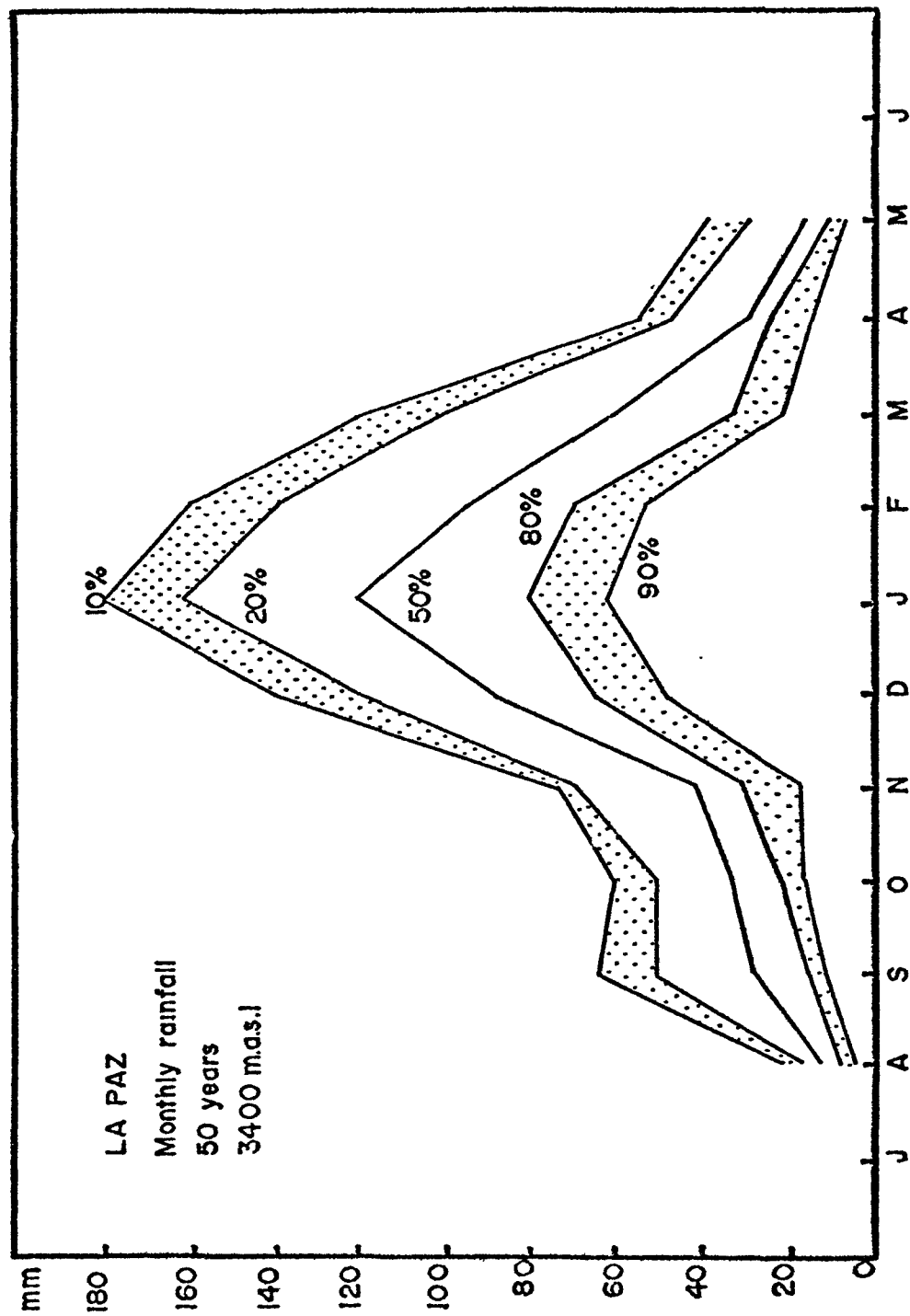


FIG.5. EXPECTED RAINFALL IN LA PAZ, BOLIVIA, 3400 M.A.S.L.

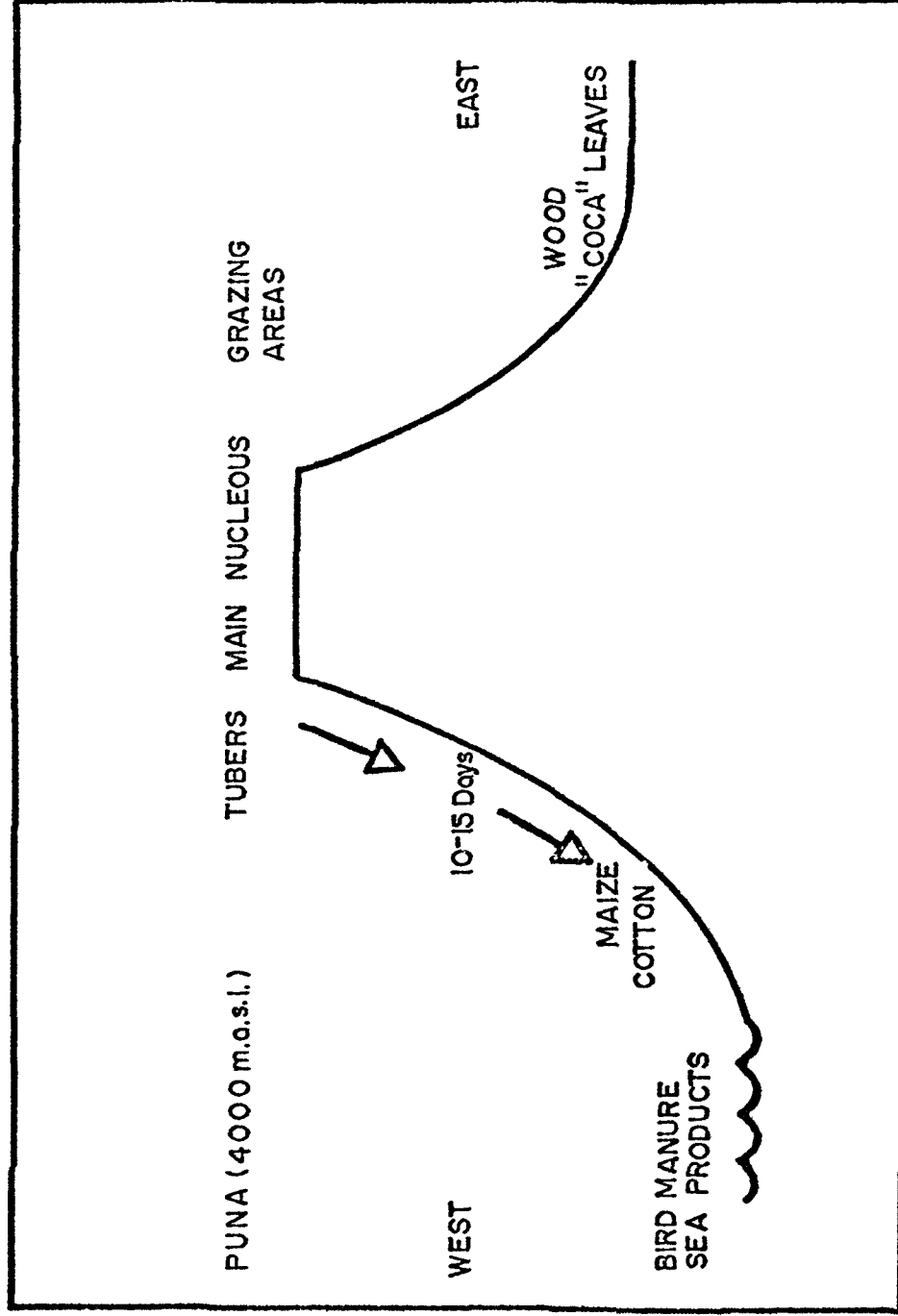


FIG.6 CROSS SECTION OF THE ANDES AS USED BY THE LUPAKAS (FROM MURRA)

H Z's P

1. Inter Andean Valleys
Foot hills.
"Jalca" (humid grazing areas)
2. Semi humid inter Andean Valleys.
"Altiña" (dry slopes)
"Puna" (semi humid grazing areas)
3. Dry inter Andean Valleys
High plateaus.
"Puna" (dry grazing areas)
4. Very dry inter Andean Valleys
Tenaced valleys.
"Puna" (very dry grazing areas)
5. "Yungas" (very humid and cloudy valley areas)
6. Lake Shores.
"Suní" (grazing semi humid plans)
"Cordillera" (extensive, dry, poor, high grazing areas)

1. Northern.
2. Central.
3. South Central.
4. Dry South West.
5. Humid Oriental Slope.
6. Titicaca High Plateau.

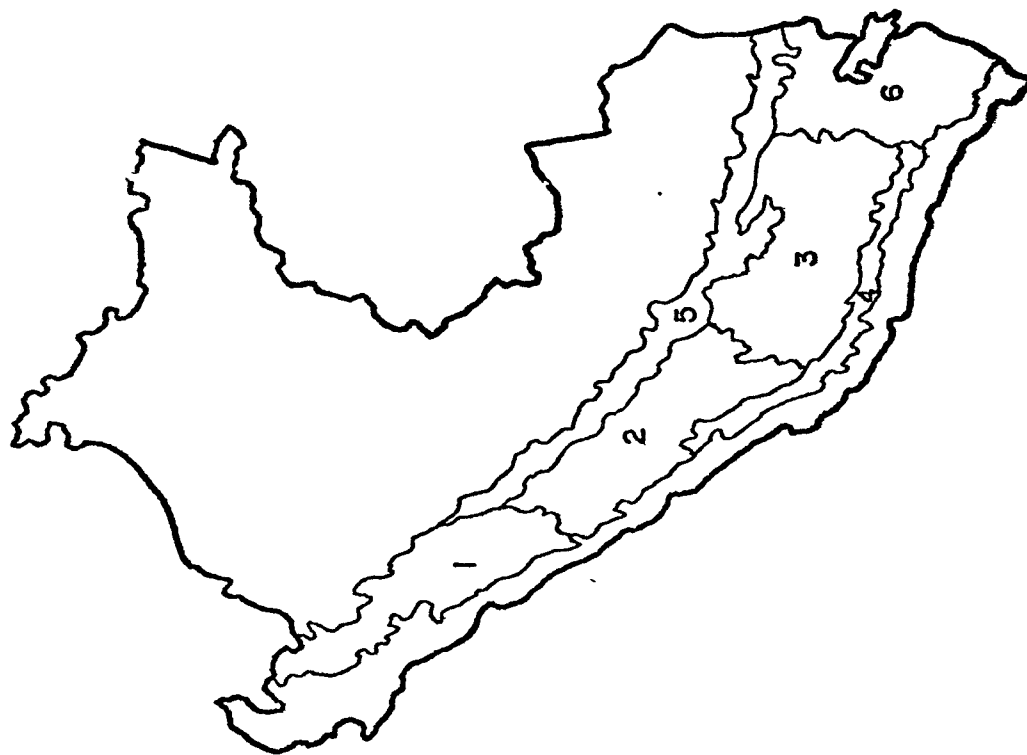


FIG.7 ANDEAN SUB-REGIONS AND HOMOGENEOUS ZONES
OF PRODUCTION IN THE PERUVIAN ANDES.

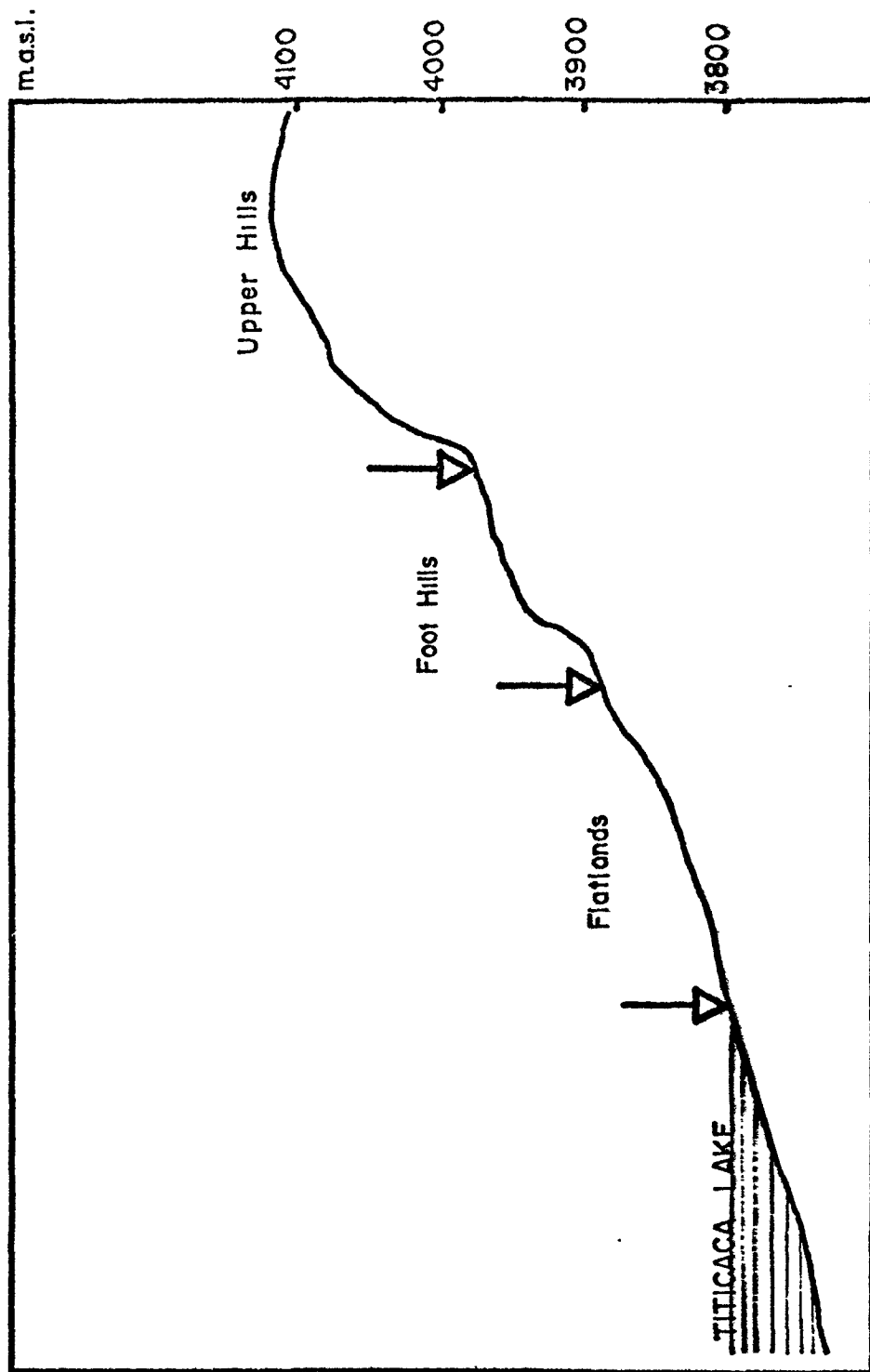


FIG. 9. HOMOGENEOUS ZONES OF PRODUCTION (HYP)
IN THE TITICACA LAKE SHORE, PERU.

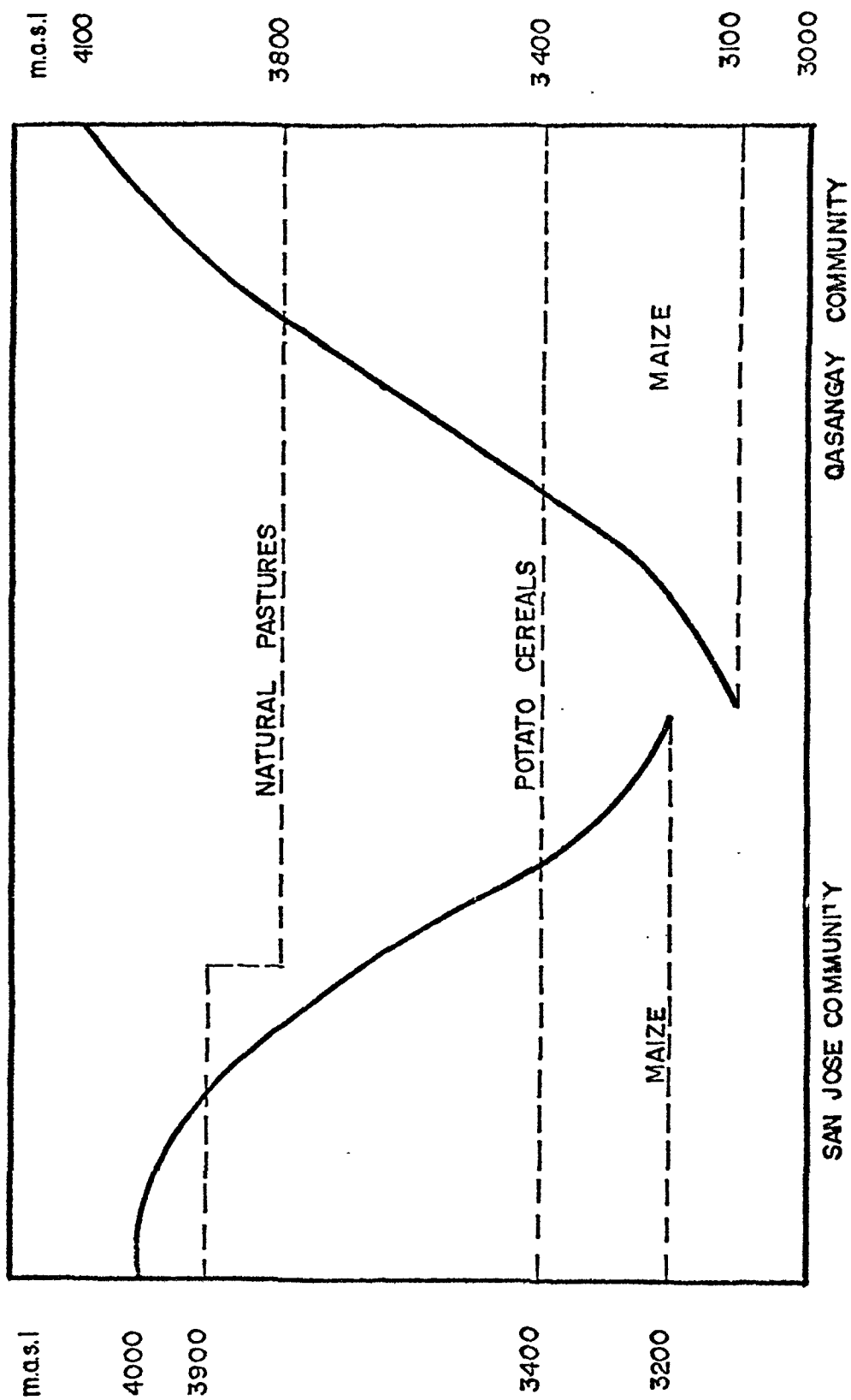


FIG.9. HOMOGENEOUS ZONES OF PRODUCTION (H2P)
AT THE AYACUCHO AREA, PERU.

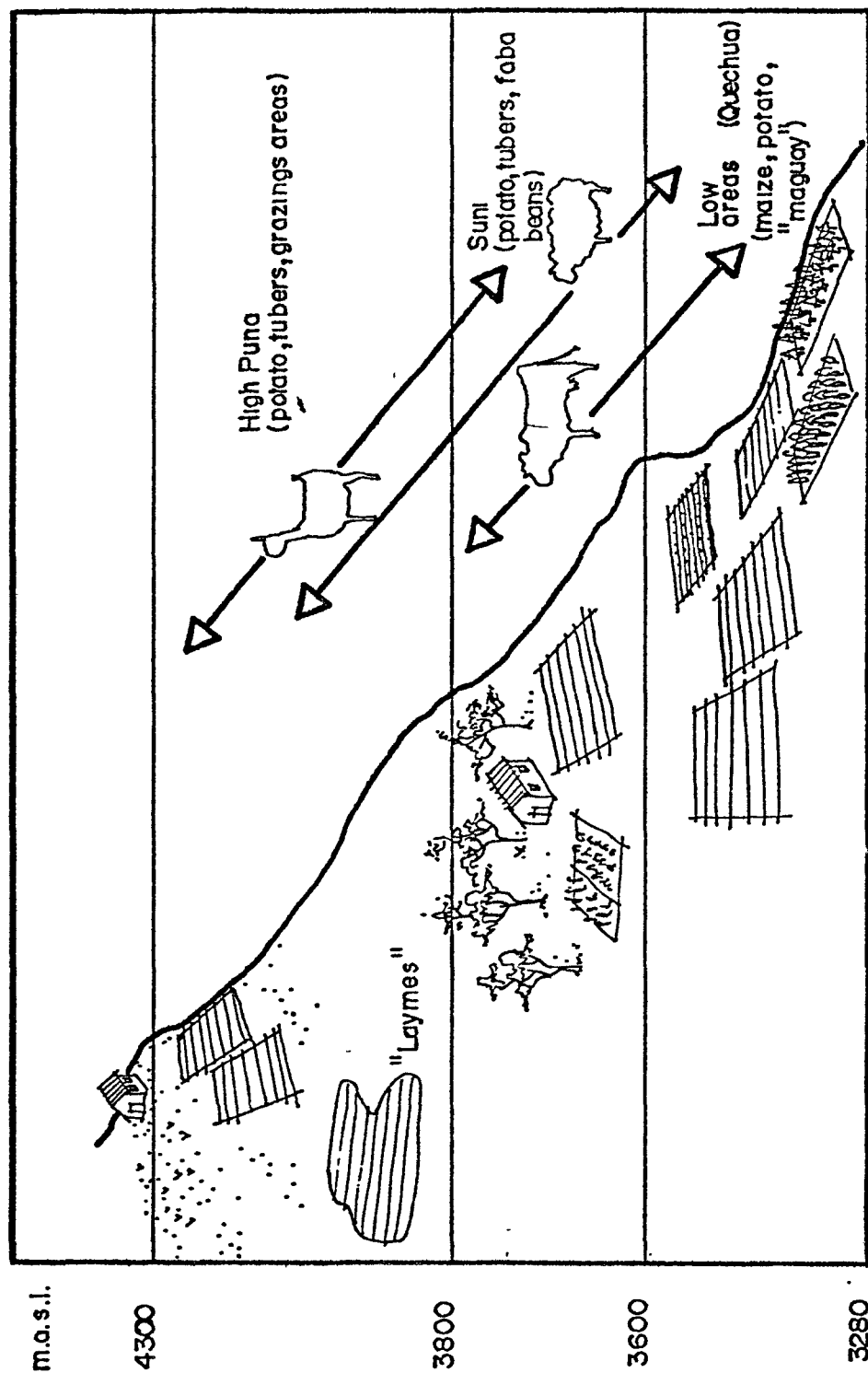


FIG.10. HOMOGENEOUS ZONES OF PRODUCTION (HZP)
IN THE CUSCO AREA PERU.

FIG.II. COMPONENTS AND INTERACTIONS OF THE AGRICULTURAL SYSTEM.
A CASE STUDY OF A FAMILY IN THE AMARU COMMUNITY, CUSCO, PERU.

